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Loss Of Load Probability Analysis For Standalone Solar Photovoltaic Power System For A Houshole In River State

Wali Samuel[1]
Department of Electrical/Electronic and Computer Engineering, University of Uyo, Akwa Ibom, Nigeria

Steve Worgu[2]
Department of Electrical/ Computer Engineering, Port Harcourt Polytechnic, Rumuola, Port Harcourt Nigeria

Abstract— **In this paper, the loss of load probability (LOLP) analysis for standalone solar photovoltaic (PV) power system for a household in River State is studies. Analytical expressions for computing Loss of Load Probability (LOLP) were presented along with the load demand of the household. Also the irradiation data of the household site, and the load demand data were used in PVSyst simulation program to determine appropriate size of the various solar PV power components. With a daily energy demand of 12642 Wh/day, the average annual energy yield is 900.94 kWh per year, the annual user energy demand is 809.65 kWh per year, the annual missed energy (that is energy demanded but not supplied due to non-availability of energy from the PV power or battery bank) is 33.70 kWh per year. In all, the PV solar power system for the case study site could only achieve 4.28 % LOLP which is satisfactory given that the maximum specified allowable LOLP is 5%.**

Keywords: Loss Of Load Probability, Standalone Power System, Energy Demand, Pvsyst Simulation Program, Missed Energy, Solar Photovoltaic

1. INTRODUCTION

In Nigeria, energy crisis has persisted for several years. Over the years, there has been poor electric power supply and low access to the national power grid [1,2,3,4,5,6,7]. As such, many people in Nigeria have resorted to alternative power supply systems. Most common alternative power supply in Nigeria has been based on the fossil fuel electric generator [8,9,10,11,12,13,14,15,16,17,18]. However, in view of its environmental friendliness and continuous drop in the cost, photovoltaic solar power supply has increasingly gained wider adoption across Nigeria [19,20,21,22,23,24,25,26,27].

In any case, the power supply based on solar energy is subject to variation in the solar radiation over the day and over the various seasons in a year [28,29,30,31]. As such, ensuring uninterrupted power supply with the solar power system is very difficult. One way to evaluate how regular the solar power system can guaranteed adequate power supply to the load is loss of load analysis [32,33,34,35,36,37]. Accordingly, in this paper, the loss load probability analysis for a solar powered household in presented. The study used the solar radiation data of the case study site along with the load demand of the household to estimate the loss of load probability and the loss of load duration. The details of the loss of load analysis using a PVSyst software is presented in the body of the paper along with the simulation results and the discussion of the results and their implications.

2. METHODOLOGY

2.1 The analytical basis for computing Load Probability (LOLP)

Loss of load occurs in an energy system when there generated energy is not sufficient to drive the load [38,39,40]. In the case of standalone solar power system, the loss of Loss of Load Probability (LOLP) can be expressed as the percentage of time in a year when the load demand is not satisfied due to inadequate energy yield from the solar power system. Also, LOLP can be expressed as a fraction in terms the ratio of the annual energy deficit to the annual energy demand. This can be expresses mathematically by considering the following key components, namely, the daily energy demand from the load ($E_{Ld(\mathrm{d})}$) the daily energy yield of the solar power system ($E_{op(\mathrm{d})}$), the daily excess energy ($E_{EX(\mathrm{d})}$), and the daily deficit energy ($E_{df(\mathrm{d})}$). The $E_{Ld(\mathrm{d})}$ is determined from the load demand profile of the case study household. In this paper, a load profile from PVSyst software is used. The daily yield, ($E_{op(\mathrm{d})}$ is given as follows in terms of PV panel area (A_{pv}), PV panel efficiency (η_{pv}), the daily solar radiation parameter (G_{av}), inverter efficiency (η_{inv}), connecting wire efficiency (η_{wire});

$$E_{op(\mathrm{d})} = \left(A_{pv}\right)\left(G_{av(\mathrm{d})}\right)\left(\eta_{pv}\right)\left((\eta_{wire})(\eta_{inv})\right) \quad (1)$$

Then, the excess energy, $E_{EX(\mathrm{d})}$), is store in the battery bank, where

$$E_{EX(\mathrm{d})} = \min(E_{op(\mathrm{d})} - E_{Ld(\mathrm{d})}) \quad (2)$$

The deficit energy on day k is obtained by considering the cumulative load demand, energy yield and excess energy from the first day (d=1) to the day k, hence;

$$E_{df(\mathrm{d})} = \min\left(0, \left(\sum_{d=1}^{k}\left[\left(E_{op(\mathrm{d})} + E_{EX(\mathrm{d})}\right) - \left(E_{Ld(\mathrm{d})}\right)\right]\right)\right) \quad (3)$$

The LOLP in terms the ratio of the annual energy deficit to the annual energy demand is given as;

$$LOLP = \frac{\sum_{d=1}^{365}(E_{df(d)})}{\sum_{d=1}^{365}(E_{Ld(d)})} \quad (4)$$

2.2 The Load Demand profile and solar radiation data for the case study load and site

The load in this study is a household located at Rumuokoro in Port Harcourt Rivers State at latitude of 4.84°and longitude of 7.03 °. The given site geo-coordinates were used in PVSyst software to download the solar radiation data from NASA portal; the setting on the PVSyst dialogue box is shown in Figure 1. The downloaded case study site global solar radiation on the optimally tilted plane (8°) of the PV panel is shown in Figure 2. The daily load demand of the household is shown in Figure 3 while the hourly distribution of the load is shown in Figure 4. The household has a daily energy demand of 12642 Wh.day (Figure 3).

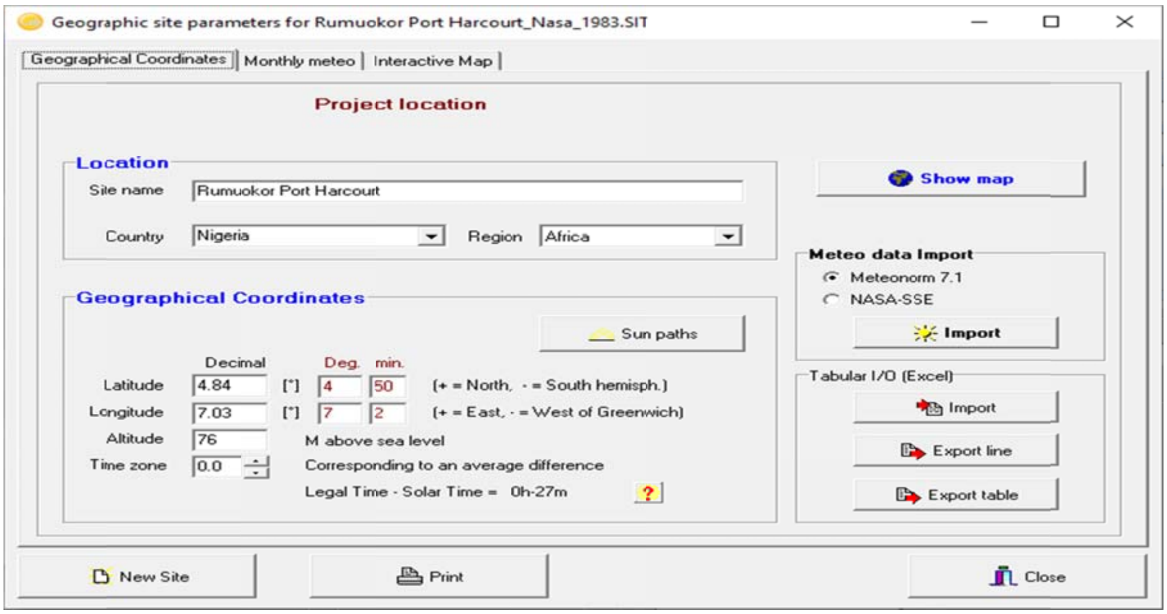

Figure 1 The setting used on the PVSyst dialogue box to download the solar radiation data from NASA portal

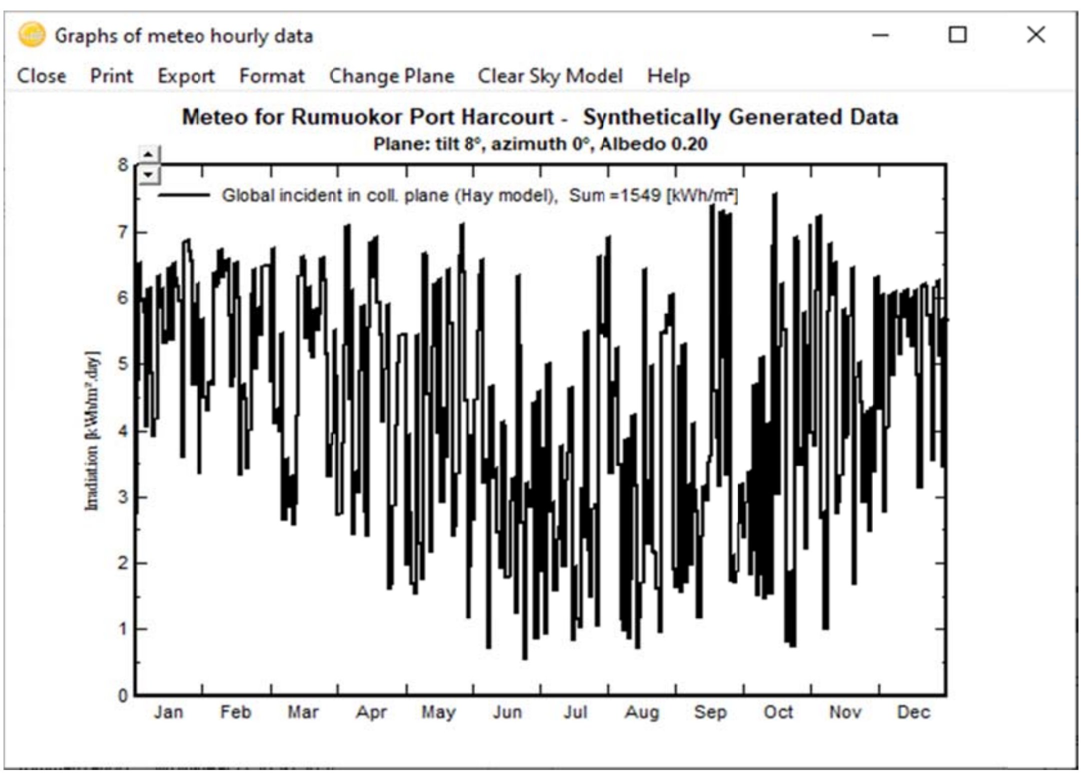

Table 2 The downloaded case study site global solar radiation on the optimally tilted plane (8°) of the PV panel

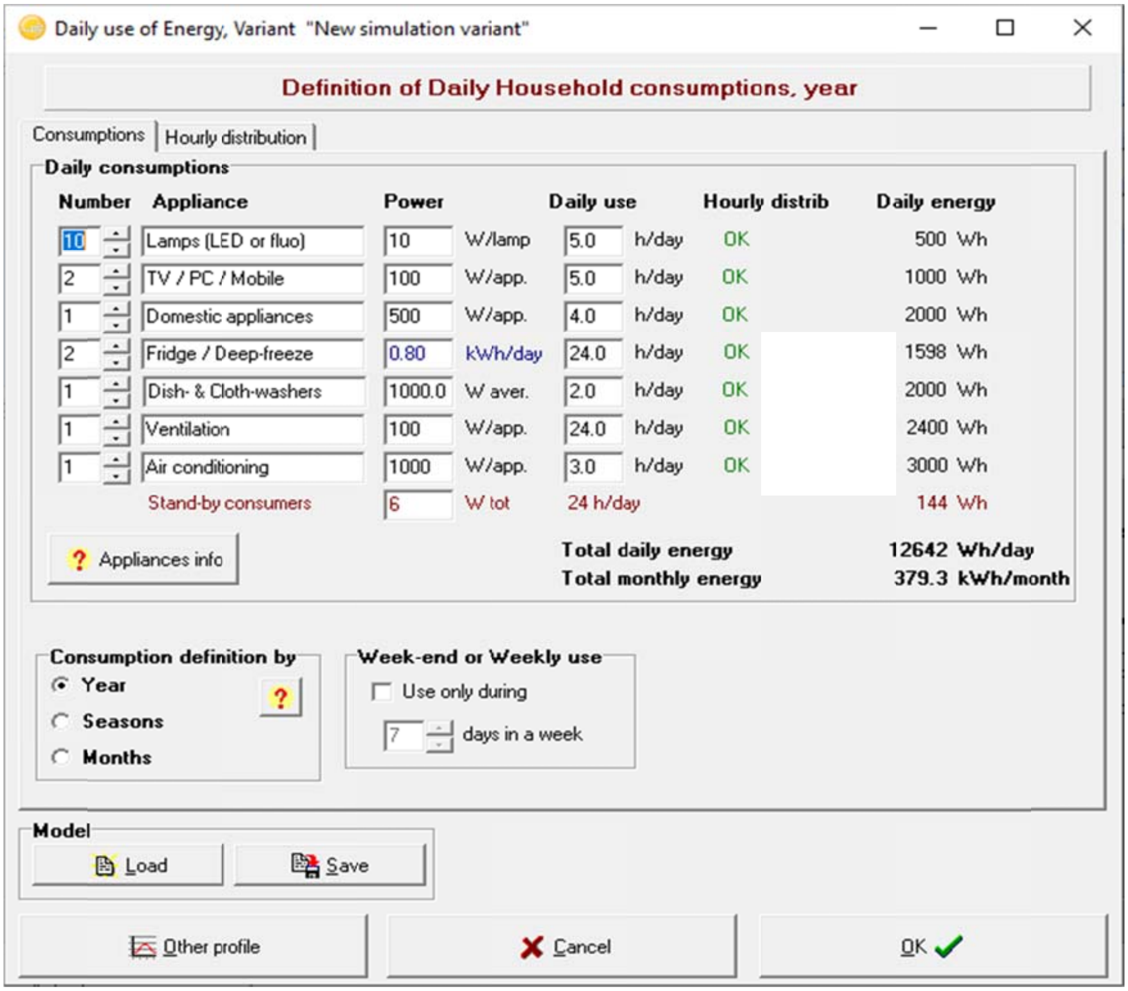

Figure 3 The load demand for the household in Rumuokoro Port Harcourt River State

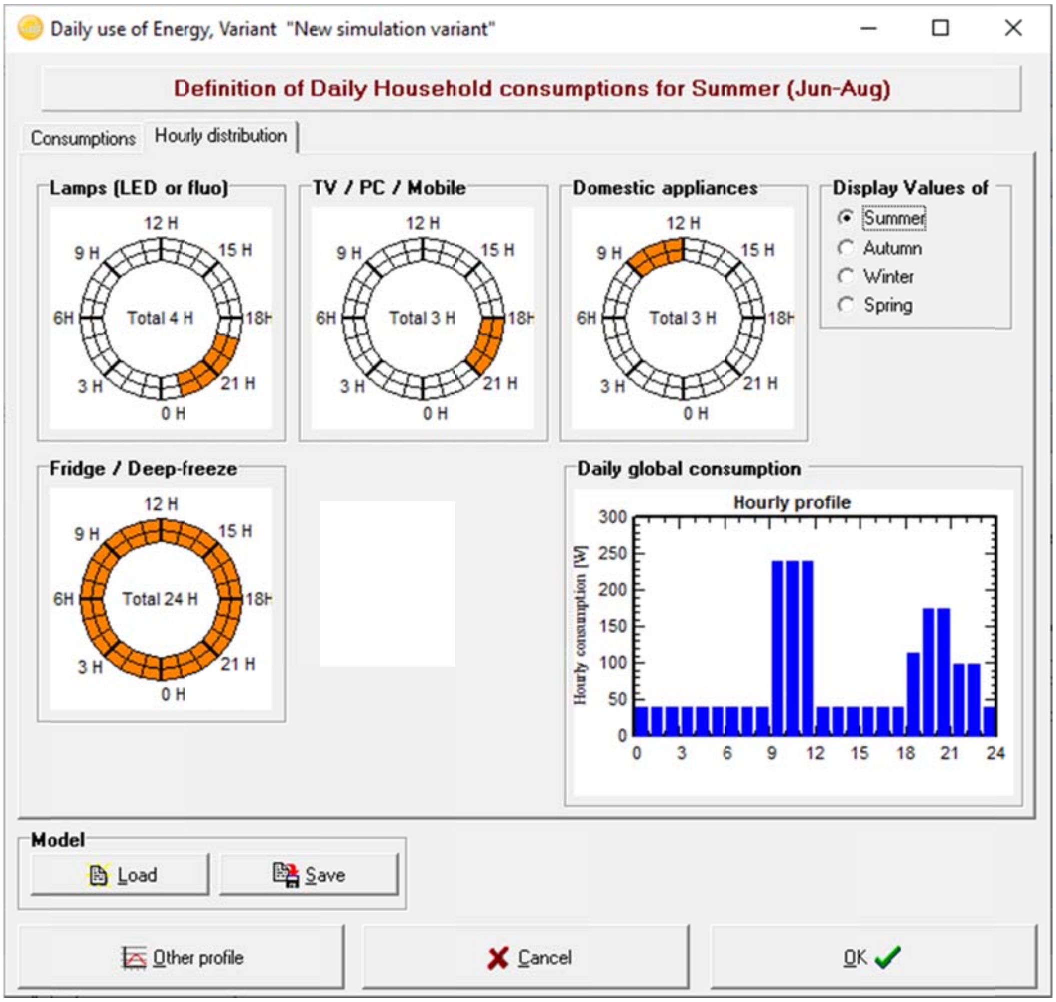

Figure 4 The Hourly Distribution of the Load

3. RESULTS AND DISCUSSION

The PVSyst simulation parameter setting for the standalone PV system showing the PV array design is presented in Figure 5. The PVSyst simulation parameter setting for the standalone PV system showing the battery bank setting is presented in Figure 6. According to the information presented in Figure 5 and Figure 6, the system has a PV array that has 3 PV modules and a battery bank that has 10 battery units. The setting is design to provide four days power autonomy and maximum of 5 % loss of load probability.

Part of the main simulation result showing the system configurtion and preformance ratio are presented in Figure 7. The simulation results showing the energy balances along with solar fraction and missing energy are presented given in Figure 8. The simulation results showing the energy usage distribution per month along with solar fraction, loss of load duration per month and load of load in percentage per month and per year are presented in Figure 9.

According to the results in Figure 8, the average annual energy yield is 900.94 kWh per year, the annual user energy demand is 809.65 kWh per year , the annual missed energy (that is energy demanded but not supplied due to non-availability of energy from the PV power or battery bank) is 33.70 kWh per year. Also, the unused energy (which is energy that is generated but wasted because the battery bank is fully charged and the load is fully supplied) is 58.10 kWh per year. The wasted energy could be harnessed if more batteries are added t the battery bank. In any case, the result in Figure 8 and Figure 9 show that the system has LOLP of 4.28% or 0.0428. This amounts to a solar fraction of 1-0.0428 ≈ 0.960 as shown in Figure 8, the last row and last column on the right. The duration of the loss of load is give in Figure 9 (the column labeled T lol) as 375 hours per year. This again can be used to determine the LOLP as follows;

LOLP= (375*100)/(24*365)=4,28%.

In all, the PV solar power system for the case study site could only achieve 4.28 % LOLP which is satisfactory given that the maximum specified allowable LOLP is 5%.

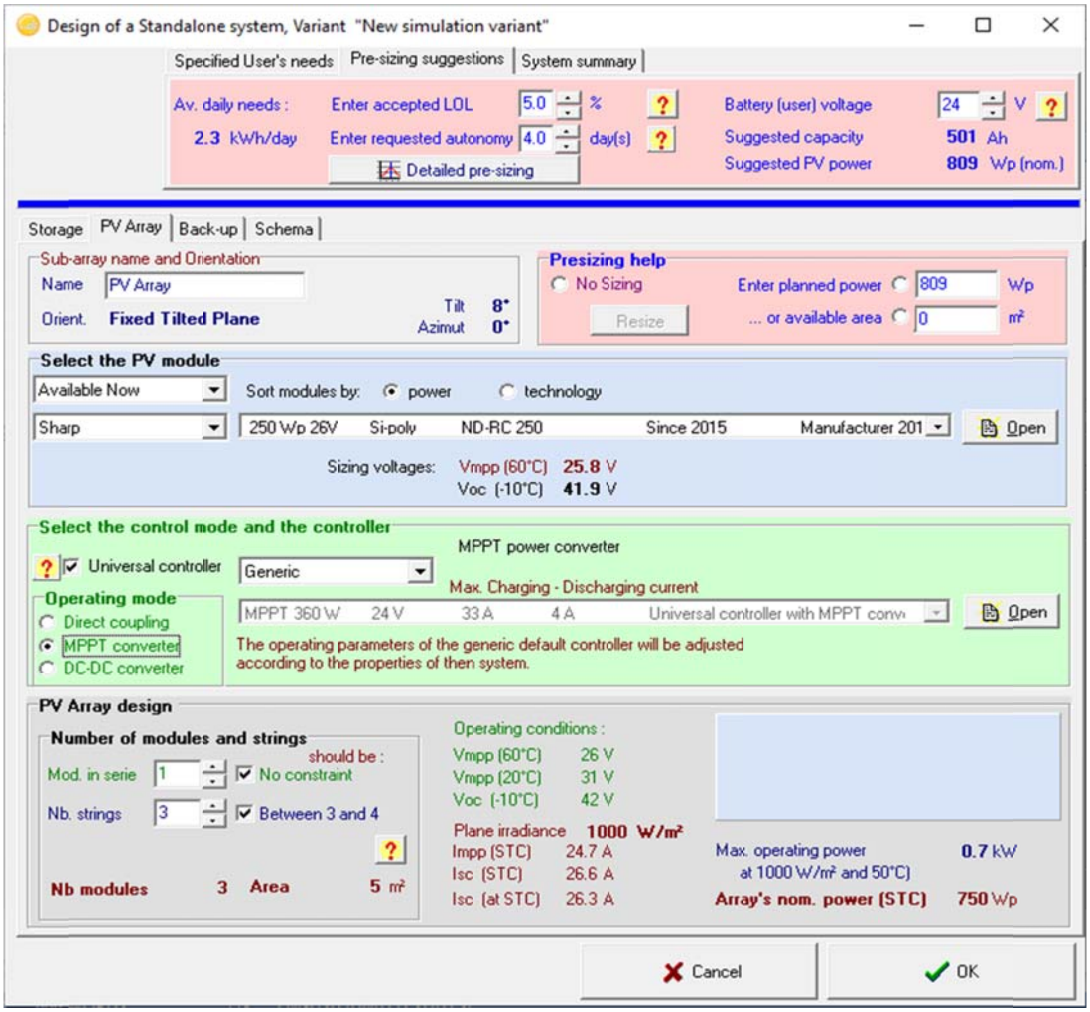

Figure 5 The PVSyst simulation parameter setting for the standalone PV system showing the PV array design

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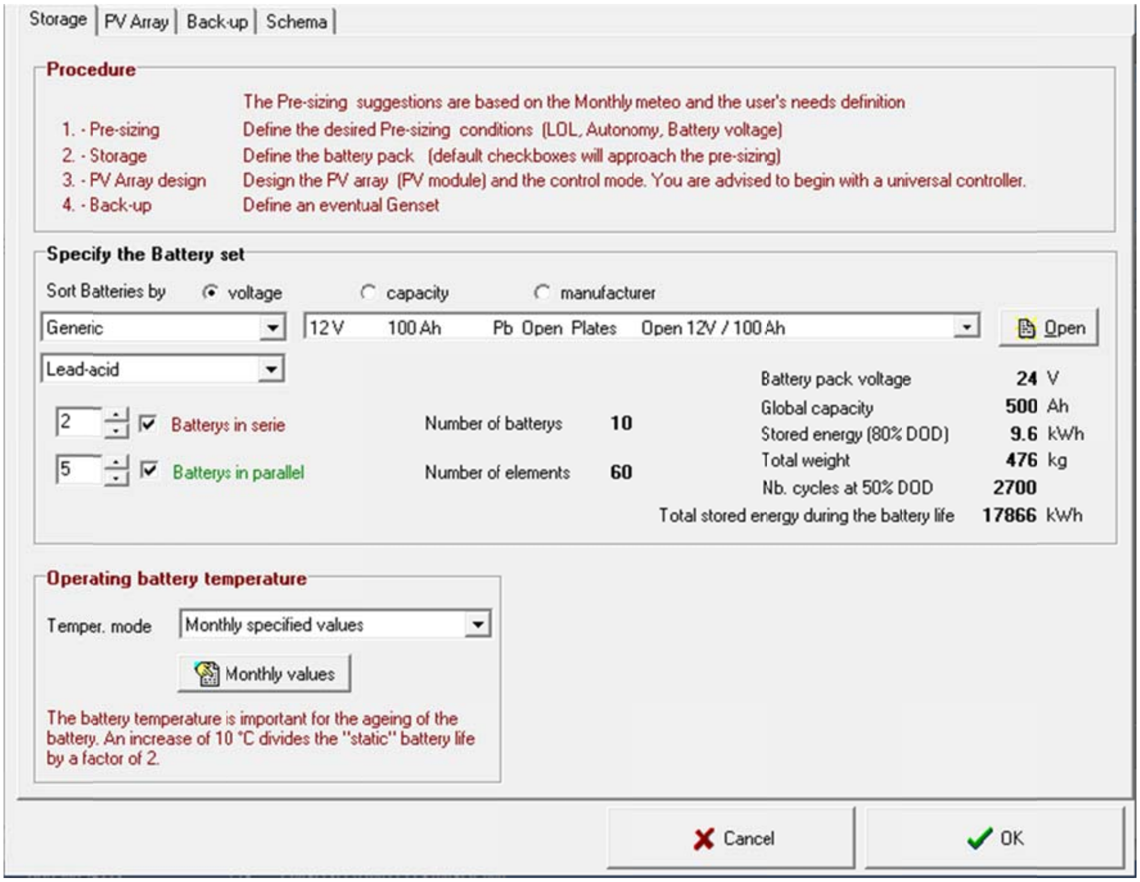

Figure 6 The PVSyst simulation parameter setting for the standalone PV system showing the battery bank configuration

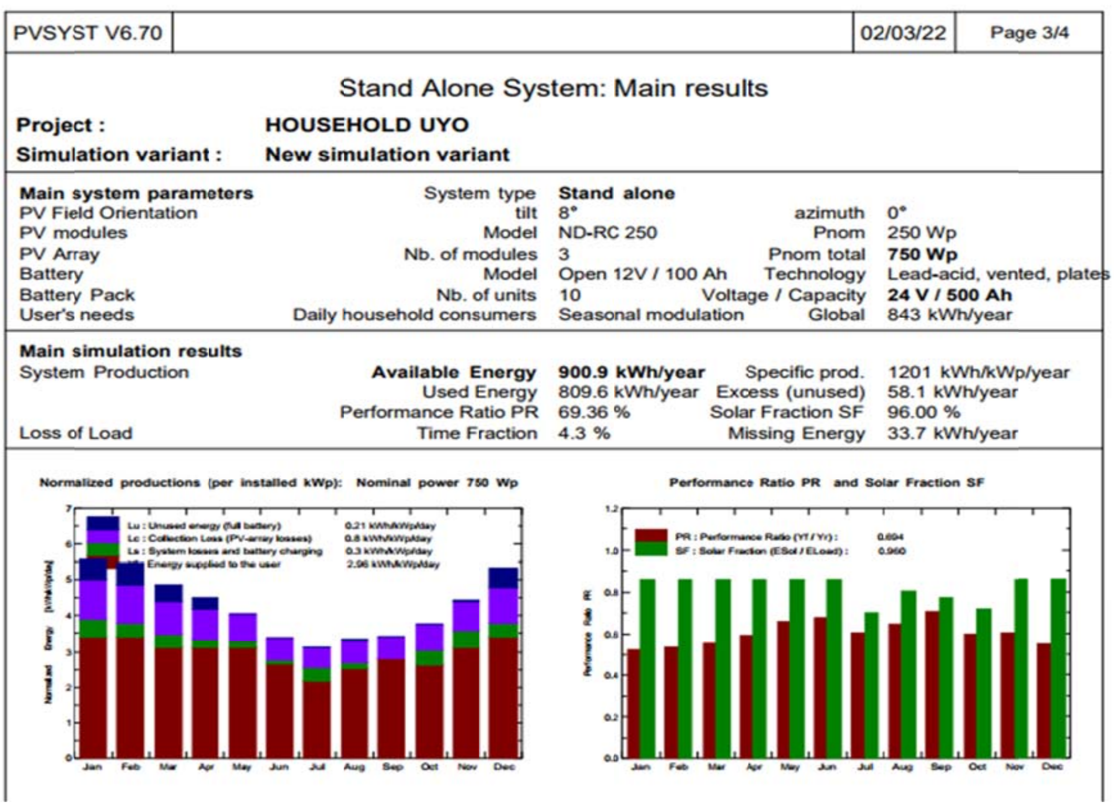

Figure 7 Part of the main simulation result showing the system configurtion and preformance ratio.

Simulation variant : New simulation variant

Close Print Export Help

New simulation variant

Balances and main results

	GlobHor kWh/m²	GlobEff kWh/m²	E Avail kWh	EUnused kWh	E Miss kWh	E User kWh	E Load kWh	SolFrac
January	161.2	167.1	99.04	13.23	0.00	79.15	79.15	1.000
February	146.7	148.5	88.00	12.67	0.00	71.49	71.49	1.000
March	148.8	145.6	87.18	10.71	0.00	72.64	72.64	1.000
April	138.0	131.0	78.35	7.32	0.00	70.30	70.30	1.000
May	131.1	121.3	72.53	0.00	0.00	72.64	72.64	1.000
June	106.2	97.5	59.12	0.29	0.00	60.25	60.25	1.000
July	100.4	92.9	56.68	0.00	11.36	50.90	62.25	0.818
August	106.0	99.6	60.32	0.88	3.83	58.43	62.25	0.939
September	102.9	98.7	59.75	0.00	6.69	63.60	70.30	0.905
October	114.1	112.5	67.16	0.02	11.82	60.82	72.64	0.837
November	126.3	128.5	77.05	0.65	0.00	70.30	70.30	1.000
December	153.4	160.2	95.77	12.33	0.00	79.15	79.15	1.000
Year	1535.2	1503.4	900.94	58.10	33.70	809.65	843.35	0.960

Figure 8 The simulation results showing the energy balances along with solar fraction and missing energy

Simulation variant : New simulation variant

Close Print Export Help

New simulation variant

Energy Use

	EArray kWh	E Load kWh	E User kWh	SolFrac	T LOL Hour	Pr LOL %
January	90.77	79.15	79.15	1.000	0	0.00
February	79.71	71.49	71.49	1.000	0	0.00
March	80.74	72.64	72.64	1.000	0	0.00
April	75.01	70.30	70.30	1.000	0	0.00
May	76.58	72.64	72.64	1.000	0	0.00
June	62.21	60.25	60.25	1.000	0	0.00
July	59.97	62.25	50.90	0.818	135	18.20
August	62.98	62.25	58.43	0.939	47	6.28
September	63.13	70.30	63.60	0.905	69	9.61
October	71.08	72.64	60.82	0.837	124	16.66
November	80.68	70.30	70.30	1.000	0	0.00
December	88.16	79.15	79.15	1.000	0	0.00
Year	891.03	843.35	809.65	0.960	375	4.28

Figure 9 The simulation results showing the energy usage distribution per month along with solar fraction, loss of load duration per month and load of load in percentage per month and per year.

4. CONCLUSION

Loss of load probability (LOLP) of standalone solar power system installed for a household at Rumuokoro in River State is presented. The required solar radiation data is downloaded from NASA portal. The system specification required days of power autonomy and maximum allowable LOLP . The PVSyst software was used to select the optimal PV module tilt angle as well as the PV array and battery bank configurations. The simulation results show that the solar power system was able to satisfy the required LOLP specification

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